Online and offline control of magnetized rotors

by Gianandrea Mazzola

The magnetic quality of magnetized rotors can be controlled from different points of view. To understand better the characteristics and the specificities about online and offline control, we have talked about that with Andrea Del Prete, VP of Magnetic Technology of Laboratorio Elettrofisico, global company specializing in the engineering, design, development and manufacture of precise magnetizing and magnetic measuring equipment

In a previous article, we described Laboratorio Elettrofisico's magnetization technology, in particular applied in the magnetization of rotors for automotive applications.

The high-quality standards of the automotive industry ask for reliable methods to verify the conformity of the final product to specific magnetic requirements.

This control is usually done in two-steps:

- 1st step: qualification of the magnetization system. This first deeper verification, usually done in the acceptance phase and sometimes in the prototype phase, has the scope to check that the magnetization system magnetizes the rotor in the correct way.
- 2nd step: 100% control of the rotor during production. Due to productivity rate requirements, it is necessarily a faster control, although it must always maintain an absolute reliability.

Qualification of the magnetization system

«*The check of the magnetization system alone* – explains Andrea Del Prete, VP of Magnetic Technology of Laboratorio Elettrofisico – *is the first obvious control. Most of the tests are done independently of the final product: waveform and max level of the current pulse, mechanical forces, cooling efficiency, electromagnetic field mapping and safe limitations, etc. All of these tests must satisfy project specifications and safety requirements*».

The second step is the research of the necessary voltage level to saturate the rotor. This can be done in different ways: by measure of the magnetizing field or by saturation curve by the rotor flux.

The measurement of the magnetic field produced by the coil should preferably be done with the rotor to be magnetized.

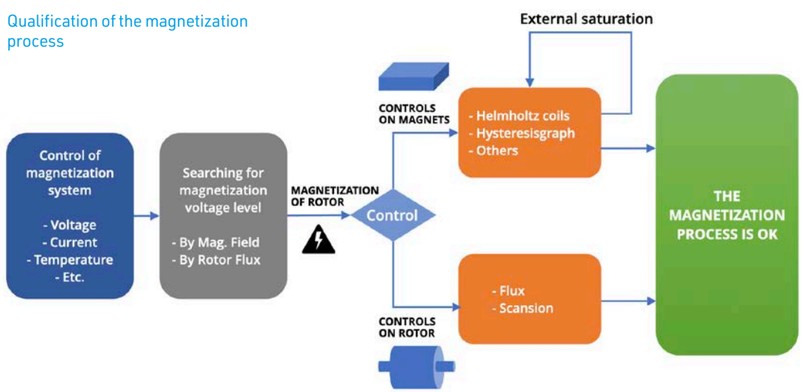
«*In this case* – underlines Mr. Del Prete – *a rotor without magnets is used; field probes and sensors are placed in the empty volume where the magnets would be inserted, possibly in different positions, to check the field even in the most unfavorable areas. Results are compared with FEA simulations and must be higher than minimum saturation requirements in all the magnet's volume*».

The field must be sufficient for the saturation, eventually with some margin, but not too abundant, to avoid unnecessary extra-heating of the coil. For this reason, the voltage is increased step-by-step until the desired field level is found.

When the voltage corresponding to this situation is found, the magnetization of a complete rotor containing virgin magnets can then be performed.

«*When the field measurement is not possible* – Mr. Del Prete highlights – *or not in all the positions inside the magnet cavities, the saturation level is evaluated initially with the measure of the total flux of the rotor at different voltage steps. The total flux is measured through measuring windings embedded in the magnetizing coil, linking all the poles of the rotor. When the flux doesn't increase anymore with the voltage, the rotor can be considered saturated, but further tests has to come yet*».

Qualification of the magnetization process



Control on the single magnets and control on the rotor

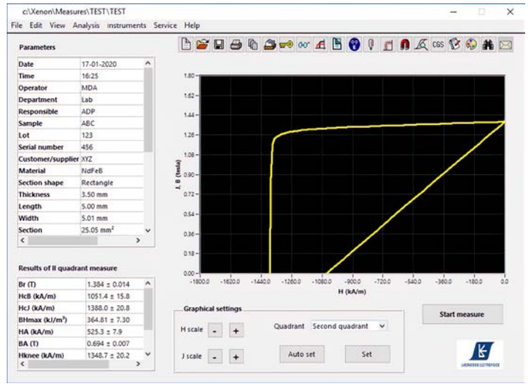
The rotor obtained by the external magnetization must be equivalent to a rotor obtained by inserting pre-saturated magnets. So, the saturation of the magnets inside the rotor must be checked. The extraction of all the magnets can be a difficult operation, especially for skewed rotors, where the removal of all the single laminations could be necessary.

«*Once all the magnets are extracted* – states Mr Del Prete – *the following controls can be done: total magnetic moment using Helmholtz coils; second quadrant curve with hysteresisgraph*».

More in detail, with total magnetic moment using Helmholtz coils. The magnets are measured one-by-one after removal from the rotor, then externally saturated with a high field and finally measured again with HC. There should be no difference between magnetic moment measured before and after magnetization.

Andrea Del Prete, VP of Magnetic Technology of Laboratorio Elettrofisico

"The magnetic quality of magnetized rotors can be controlled from different points of view. During production, we go towards configurations where, in a single solution, the product is magnetized and then immediately controlled not only by the conventional total flux but also through a complete magnetic scansion. In this way, the rotors can be 100% controlled without any delay on the production capability."



The characterization of permanent magnets with hysteresisgraph (in the picture, measuring system AMH-500, manufactured by Laboratorio Elettrofisico)

With second quadrant curve with hysteresisgraph, again, the measure of the magnets after removal is compared with the one after subsequent magnetization. This test is more complete respect the previous, because the entire curve is controlled, from Br to up to the intrinsic coercivity HcJ. The system used for this control and an example of curve is shown in the figure.

«*There are other tests on the magnets, less frequent* – adds Mr Del Prete – *such as the complete surface scansion on the single magnets, the second quadrant curve at a high temperature etc. All tests are done before and after external saturation: we are not looking on material characteristics, but differences between magnetization inside the rotor and external magnetization*». Of course, it can happen that, even if the magnets do not increase their levels after external saturation, the levels remain below the minimum acceptance. In this case, this is a problem related to the material characteristics, and not with the magnetization. The quality control of the material can only be done on a statistical base measuring a certain number of magnets with hysteresisgraph.

«*The main controls on the rotor* – Mr Del Prete points out – *are the flux control and the magnetic scansion. Since both these tests can be done also online, after the magnetization and during production, they will be described below*».

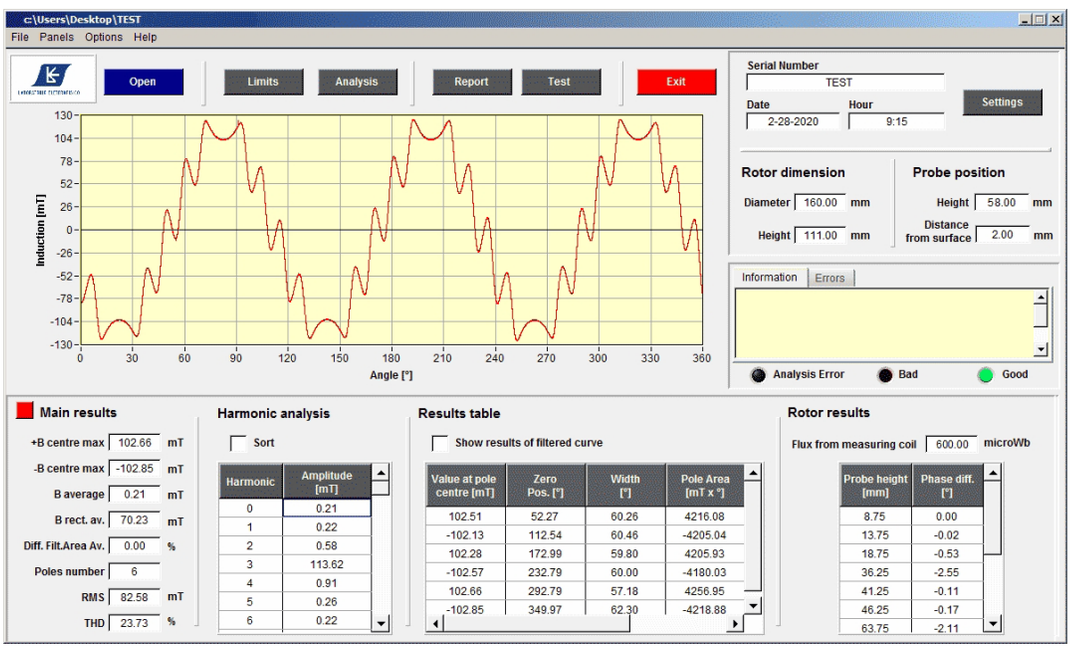
The measure of magnetic moment with Helmholtz coils (in the pictures, connected to a fluxmeter)

By on-line controls to off-line scansions

Once the system is placed in a production line, much faster controls are required on the rotors. A very first check should verify that the discharge was correctly done, for example measuring the peak level of the current pulse.

On the rotor side, the most typical and simple control is the total flux generated by the rotor itself, after the magnetization. The magnetic flux is a well-defined quantity, but in this case it should be considered as a comparative number to qualify the product instead of an intrinsic characteristic of the rotor, since it depends on the characteristics of the measuring coil: number of turns, geometry and dimensions of the coil, coil-rotor distance, ferromagnetic material present, etc.

«*The flux* – specifies Mr Del Prete – *is measured by an instrument called fluxmeter. The fluxmeter is an electronic integrator, which provides the flux*



Example of results output after an in-line scansion of a rotor

variation between the starting and ending point of the measurement. By starting the measurement with the rotor fully inserted, and terminating the measurement with the rotor fully extracted, the integration of the induced voltage across the measuring coil during the extraction time provides the total flux. It is clear that the flux alone, although important, does not guarantee that small parts of the rotor will not have defects. For example, thinking of a rotor with many magnets, if one of them was defective by a few percent, the defect would be 'masked' by the rest of the good magnets».

For this reason, a deeper control of the external magnetization of the rotor is becoming increasing popular: the online magnetic scansion.

A magnetic scanner is basically a system that measures the magnetic field produced by the rotor in its external surface. The scansion, at a certain axial level, is done placing a field sensor in proximity of the surface and rotating the rotor in a complete turn, measuring the field vs. angle.

This procedure can be repeated then for any different axial level, defined by the user.

«*It is obvious that* – highlights Mr Del Prete – *in a magnetizing bench, the rotation and the axial displacement are already provided by the bench, so the addition of a magnetic scanner is a very convenient option, since relatively few other instruments are necessary. The scansion provides a much more complete image of the quality of the final product: complete waveform with maxima, minima, pole width, skewing angle, harmonics, and many others*».

Based on parameters and limits pre-defined by the user, the scansion immediately provides the conformity of a product respect the target. In this way, the product can proceed to the next stage of the production or kept apart for further analysis of the non-conformity.

A magnetic measuring scanner, the new Magnetoscan is designed by Laboratorio Elettrofisico to measure the magnetic field generated by permanent magnet devices that exhibit axial or radial multipolar magnetization, as is the case with rotors or stators

The on-line magnetic scansion of rotors

All the measured data are stored in the industrial PC of the bench and can be managed in customable ways by the internal network. For example, the data can be controlled in a deeper way offline, even if measured online, to produce more detailed report respect those possible online.

The scansions are generally performed on multiple levels, both using a single field probe and performing multiple scans, or using multiple probes, allowing the acquisition of the field at multiple levels simultaneously in a single rotation. In the latter case, of course, the scan times are significantly reduced, considering that a rotation takes about 5 seconds.

Although the on-line scansion is very practical and convenient, when the production time is very limited or when the type of control is very deep and must be processed by expert operators, the scansion can be done in an offline laboratory bench, separated by the production bench. For example, this could be the case when many different levels must be checked, or for statistical deeper controls on production parts.

«*In conclusion* – ends Mr Del Prete – *the magnetic quality of magnetized rotors can be controlled from different points of view. During production, we go towards configurations where, in a single solution, the product is magnetized and then immediately controlled not only by the conventional total flux but also through a complete magnetic scansion. In this way, the rotors can be 100% controlled without any delay on the production capability*».